

# Climate Change & Sea Level Rise

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*Delaware's Sea Level Rise Initiative*



# Definitions

- **Climate Change:** any significant change in measures of climate (such as temperature, precipitation, or wind) lasting for an extended period (decades or longer).
- **Global Warming:** an average increase in the temperature of the atmosphere near the Earth's surface, which can contribute to changes in global climate patterns. It can occur from a variety of causes, both natural and human.

# Consequences of Climate Change (IPCC, 2007)

## ■ Precipitation

- ✓ An increase average annual precipitation, will vary by region.
- ✓ An increase in the intensity of precipitation events, particularly in tropical and high-latitude
- ✓ Reduced rainfall over continental interiors during summer

## ■ Storms

- ✓ Mid-latitude storm tracks are projected to shift toward the poles, with increased intensity in some areas but reduced frequency.
- ✓ Tropical storms and hurricanes are likely to become more intense

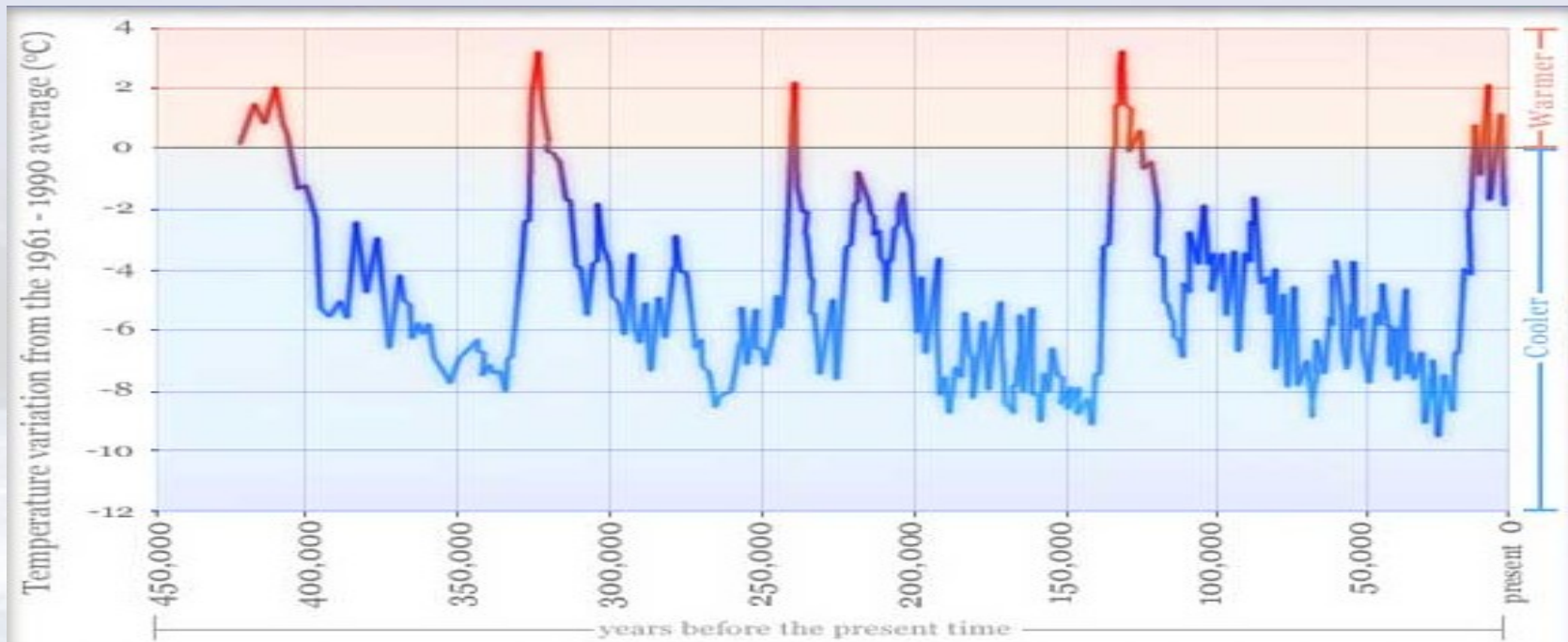
## ■ Temperature

- ✓ The average surface temperature of the Earth is likely to increase by 3.2 to 7.2°F (1.8-4.0°C) by the end of the 21st century.

## ■ Sea Level



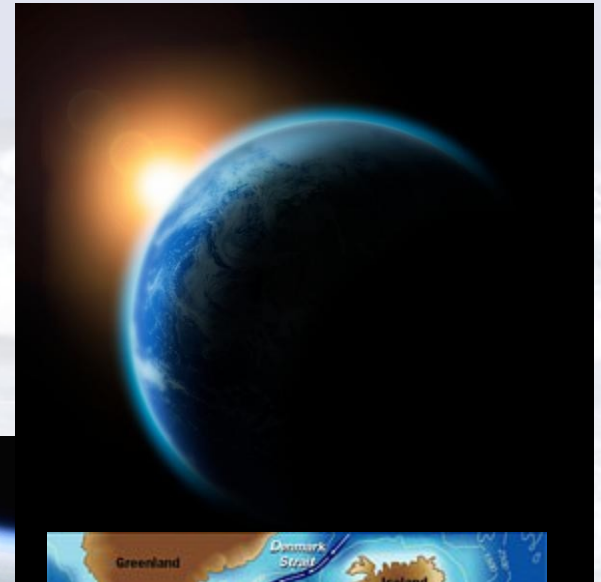
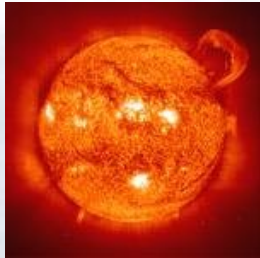
# Historic Global Temperature Variation



Source: Petit, J.R., et al., 2001, Vostok Ice Core Data for 420,000 Years, IGBP PAGES/World Data Center for Paleoclimatology Data Contribution Series #2001-076. NOAA/NGDC Paleoclimatology Program, Boulder CO, USA

# Natural Factors Affecting Global Temperatures

- Variations in Earth Orbit/Rotation
- Solar Activity
- Volcanoes
- Circulation Patterns
- Greenhouse Gases

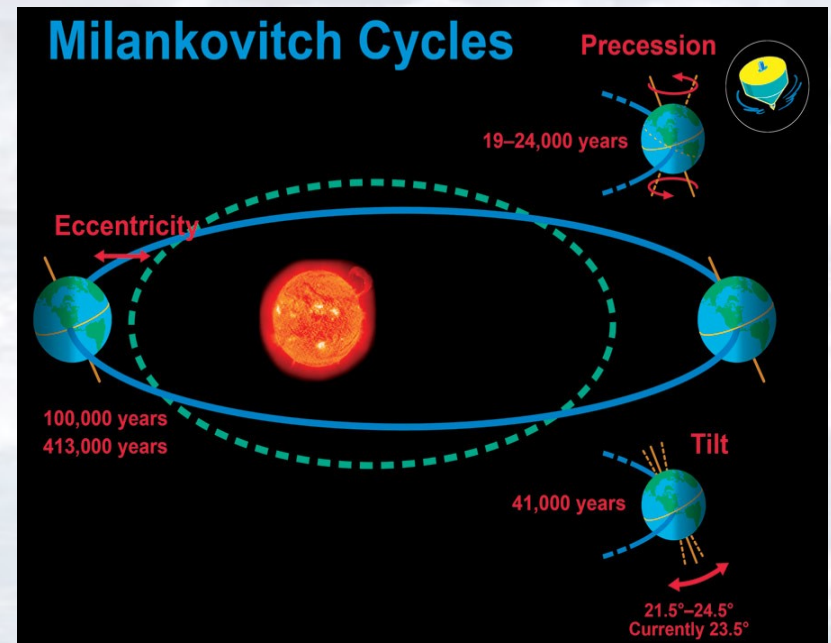




# Earth Orbit/Rotation

- Astronomical factors affecting incoming solar radiation explain 85% of temperature change

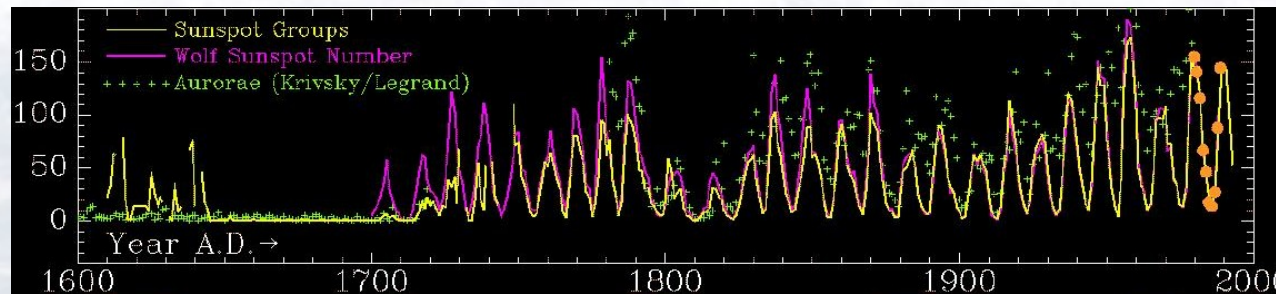
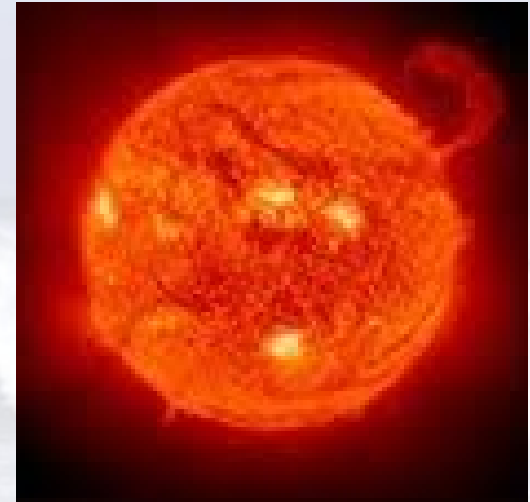
- ✓ Eccentricity ~ 50%
  - 3% Change in Orbit
  - 100- 400,000 years
- ✓ Tilt ~ 25%
  - 3° Change in Axis
  - 41,000 years
- ✓ Precession ~ 10%
  - Direction of tilt
  - 19-24,000 years



Source: Hays et.al., *Science*, December 1976

# Sunspot Activity

- 11 year & 90 year cycles
- Varies solar input by ~0.1%
- Maunder Minimum 1645-1715 – “Little Ice Age”



# Volcanoes

- Ash Emissions

- ✓ Stay suspended ~ 6 months
- ✓ Reflect solar radiation - *Cooling*

- CO<sub>2</sub> Emissions

- ✓ Annual average 200 million tons
- ✓ Greenhouse Gas – *Warming*

- Sulfur Dioxide Emissions

- ✓ Combines with water vapor to form clouds of sulfuric acid
- ✓ Persist in stratosphere ~ 3 years
- ✓ Reflect solar radiation – *Cooling*

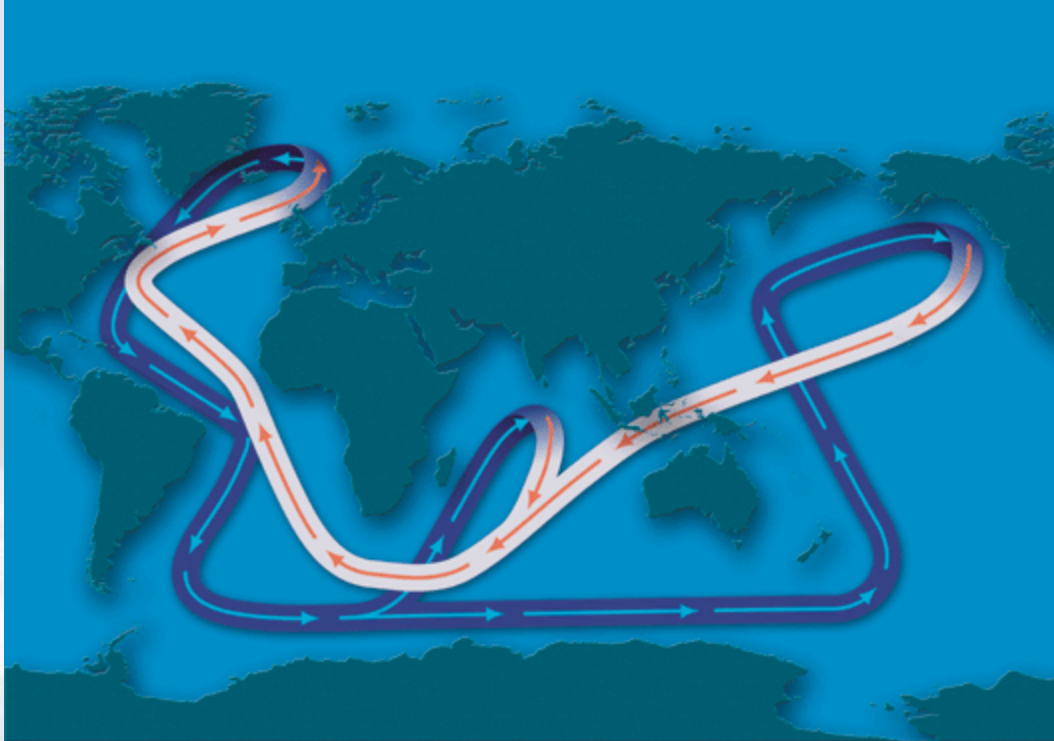
- Net Effect

- ✓ Recorded global temperature changes of -0.5 to -3°C (-1 to -5.5°F )





# Ocean Circulation Patterns



- Moderates Earth's climate
- Breakdown of system could be factor in reaching “tipping point”

Source: WHOI / Gagosin

# Greenhouse Gases (GHG)

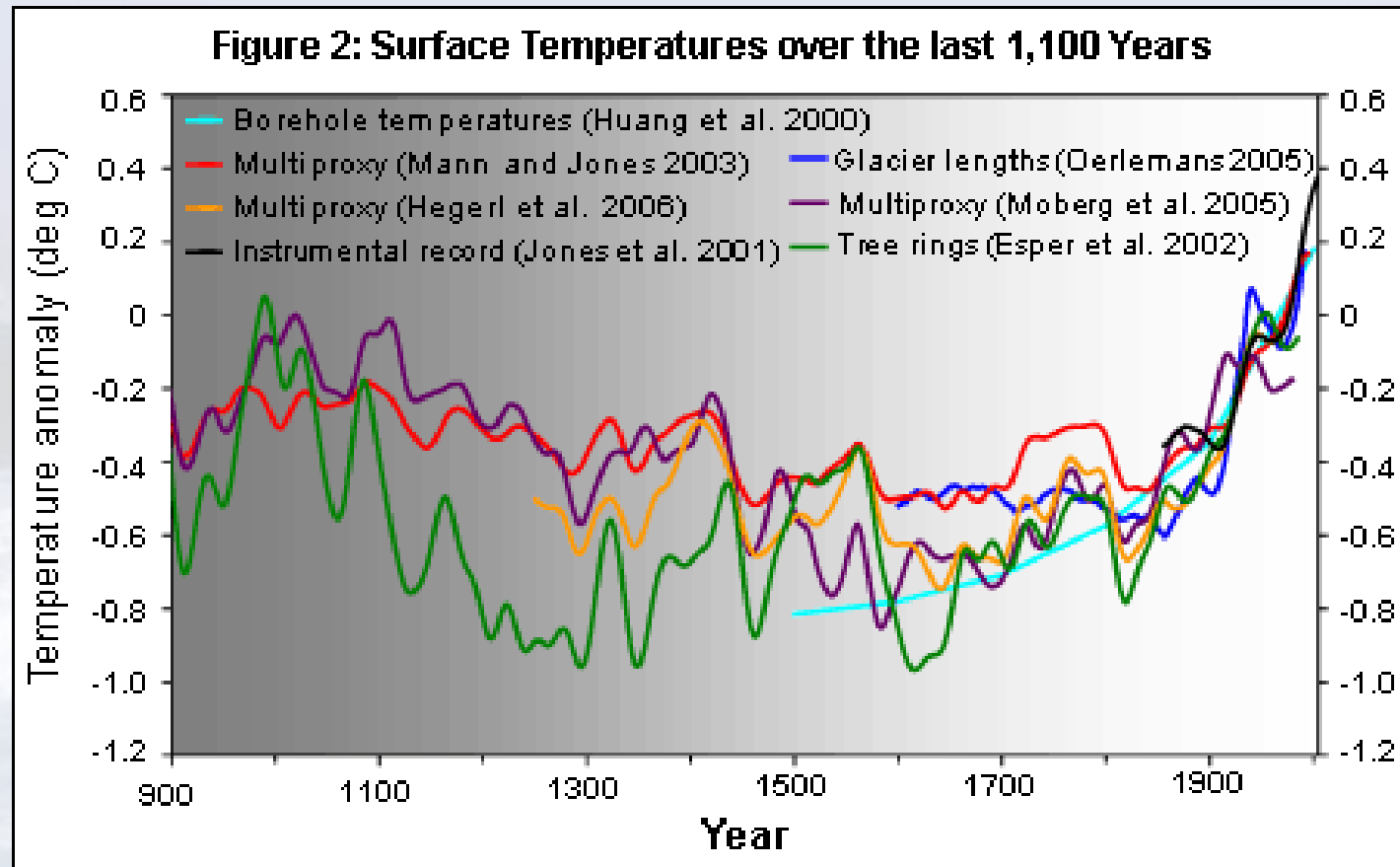
- Called GHG because they allow the shortwave energy (sunlight) to reach earth and then trap the longwave energy (heat) radiating from the surface.
- Natural: Water Vapor, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O
- Manmade: CFCs, HFCs, PFCs
- Historic CO<sub>2</sub>: 180-300 ppmv
- Without GHG the Earth would be 33°C (60°F) cooler



# Feedbacks

- Feedbacks can increase or decrease global warming
- **Positive Feedback:** shrinking ice sheets would decrease surface reflection (albedo), increasing solar energy absorption, increasing temperatures and accelerating ice melt
- **Negative Feedback:** warming would increase evaporation which would increase cloud cover, the additional clouds would reflect more solar energy, thus decreasing temperatures.

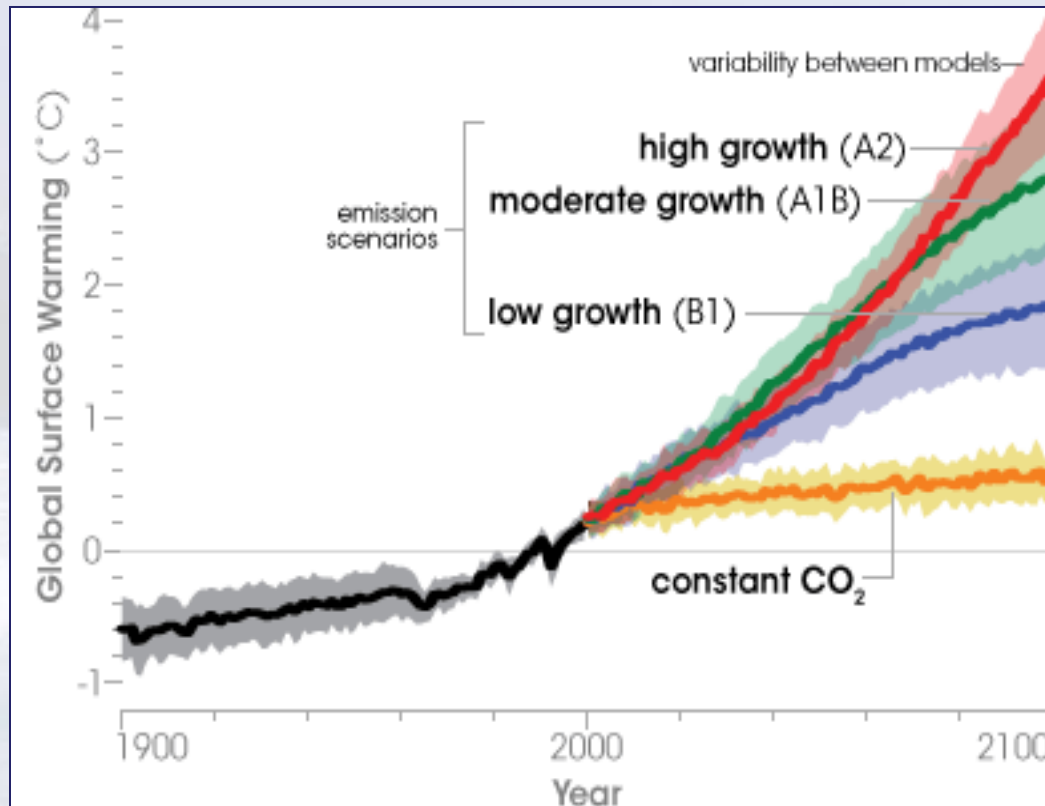
# Global Surface Temperature



Source: National Research Council



# Future Emissions and Global Temperature



Human activity emits 24 billion tons/year of CO<sub>2</sub> or about 150 times as much as volcanic activity

Current CO<sub>2</sub> level 387 ppmv (October, 2010)

Source: IPCC, EPA, NOAA

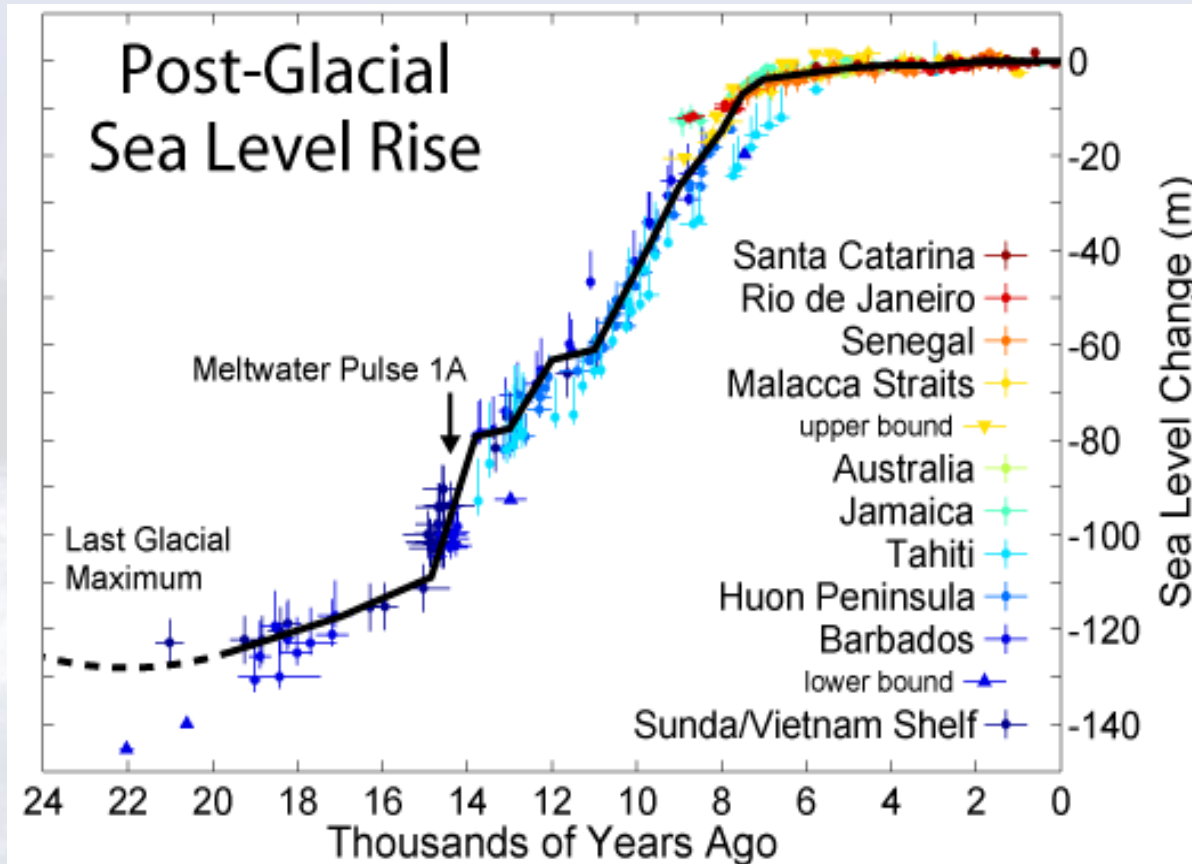
# From The Sun to the Seas



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# Global Sea Level – Past 20,000 Years

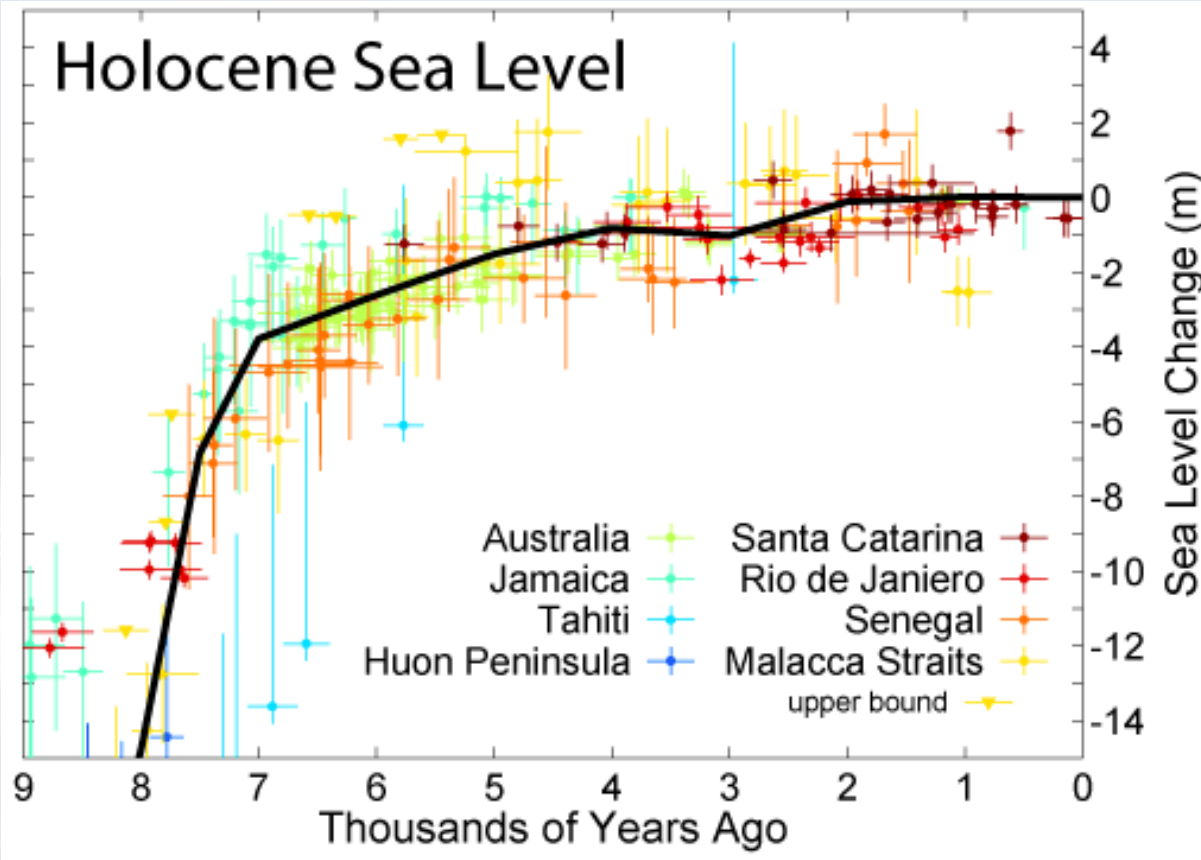


*Past 20,000 years*

**120 m or  
400 feet**

Source: Fleming et al. 1998, Fleming 2000, & Milne et al. 2005

# Global Sea Level – Past 7,000 Years



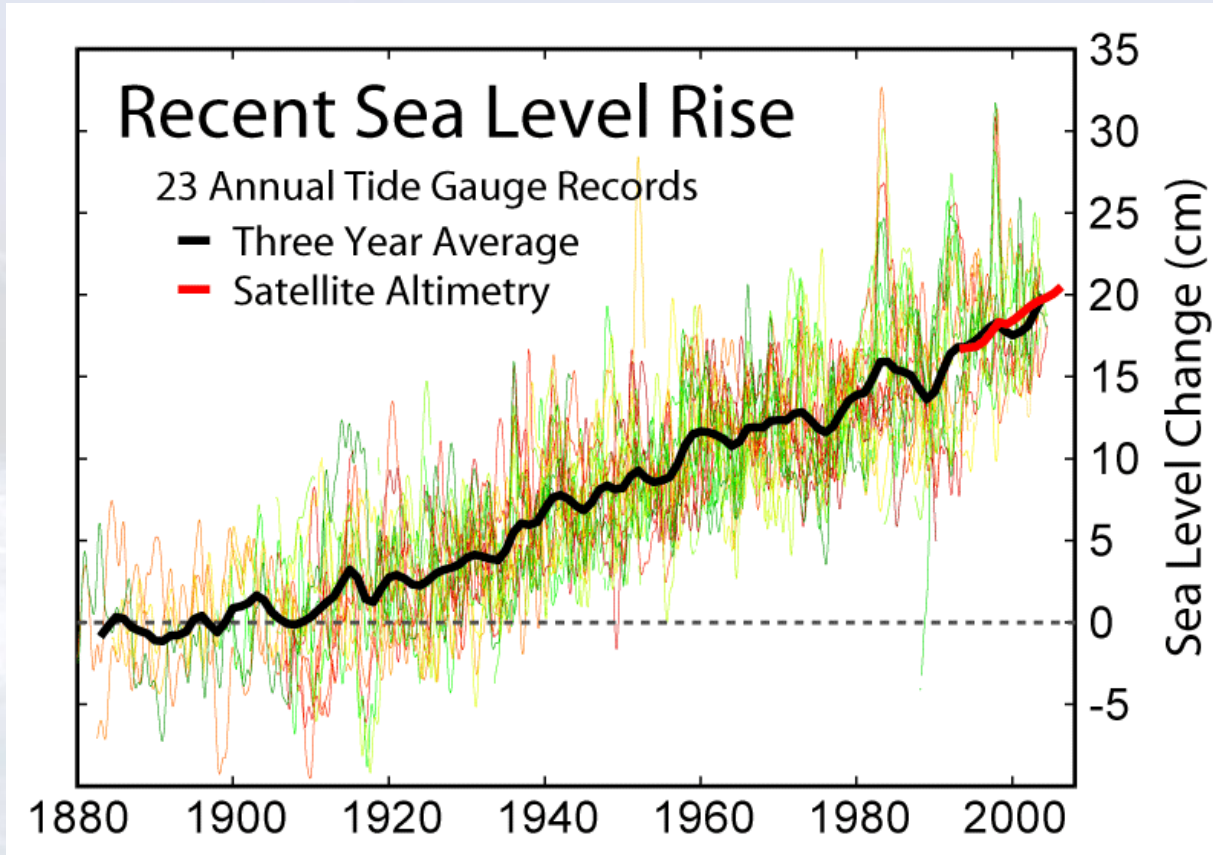
*Past 7,000 years*  
**3.5 m or**  
**11.5 feet**

*Annual Rise*  
**0.5 mm/yr**

Source: Fleming et al. 1998, Fleming 2000, & Milne et al. 2005



# Global Sea Level - Past 100 Years



*Past 100 years*  
**17 cm or  
7 inches**

*Annual Rise*  
**1.7 mm/yr**

Source: Bruce C. Douglas (1997). "Global Sea Rise: A Redetermination".  
*Surveys in Geophysics* **18**: 279-292



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# Factors of Sea Level Change





# Thermodynamics

- Historic global temperature variation between ice ages is **10-13°C (18-23°F)**
- For every 1°C ocean water is warmed sea level would rise **70 cm (28 in)**
- A 12 °C temperature change would equal sea level change of **8.4 m (27 ft)**



# Glaciers

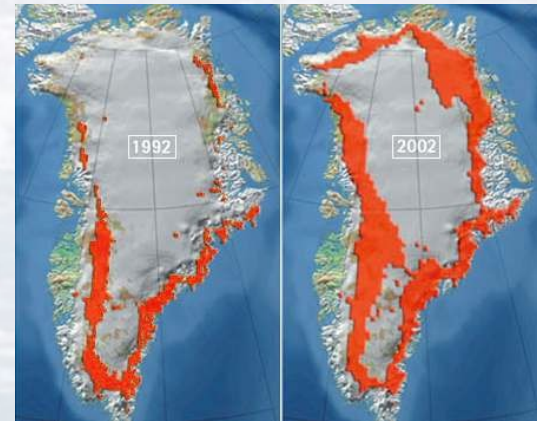
- 20,000 years ago, at the peak of the last ice age glaciers covered:
  - ~ 8 % of Earth's surface
  - ~ 25 % of Earth's land area
- Today, glaciers cover:
  - ~ 3.1 % of Earth's surface,
  - ~ 10.7 % of Earth's land area



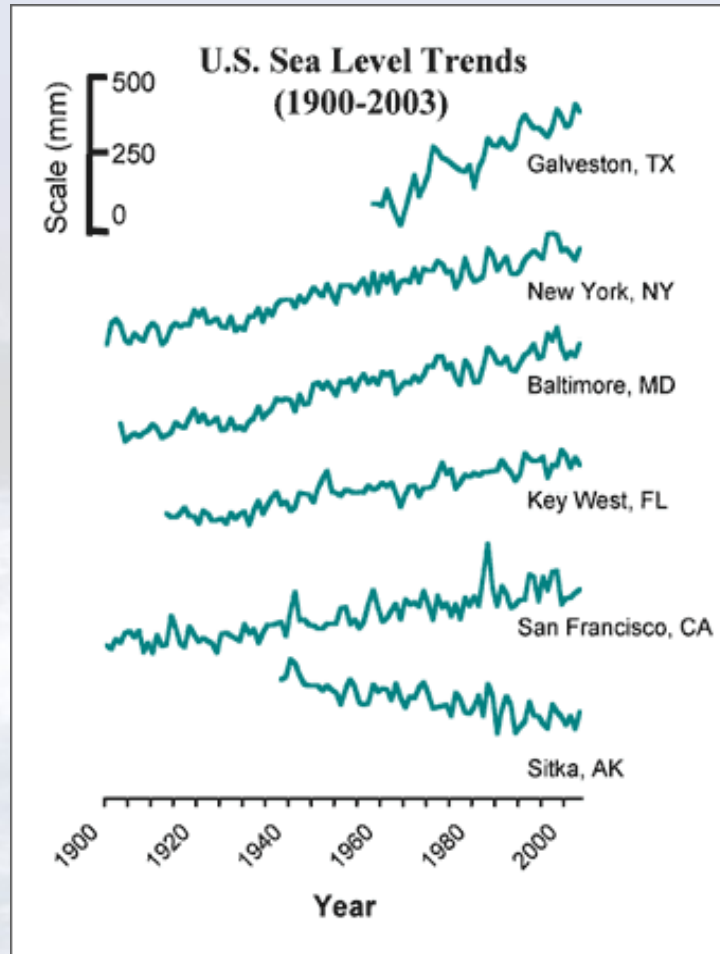


# Glaciers – How Much Is Left?

- Greenland Ice Sheet
  - ✓ 6.5 meters of Global SLR
- Western Antarctic Ice Sheet
  - ✓ 8 meters of Global SLR
- Eastern Antarctic Ice Sheet
  - ✓ 65 meters of Global SLR
- Other Glaciers and Ice Fields
  - ✓ 0.5 meters of Global SLR



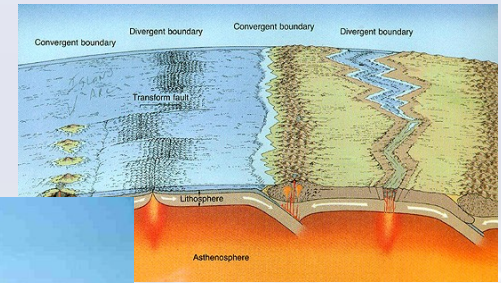
# Local Sea Level Rise (Change)



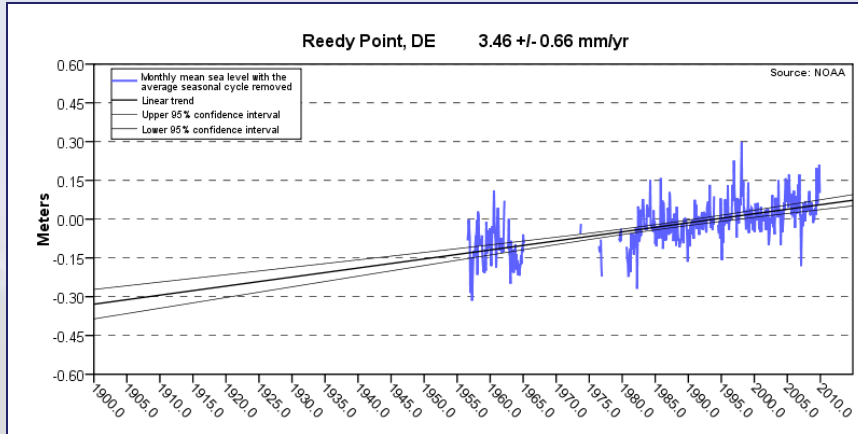
Local Sea Level  
change rates can  
vary throughout  
the world

# Reasons for Changes in Local Sea Level

- Tectonic Activity
  - ✓ Tectonic plate movement
  - ✓ Interglacial Rebound
- Surface Subsidence
  - ✓ Water Withdrawal
  - ✓ Oil and Gas Withdrawal
- Other Factors
  - ✓ Compaction of Sediments



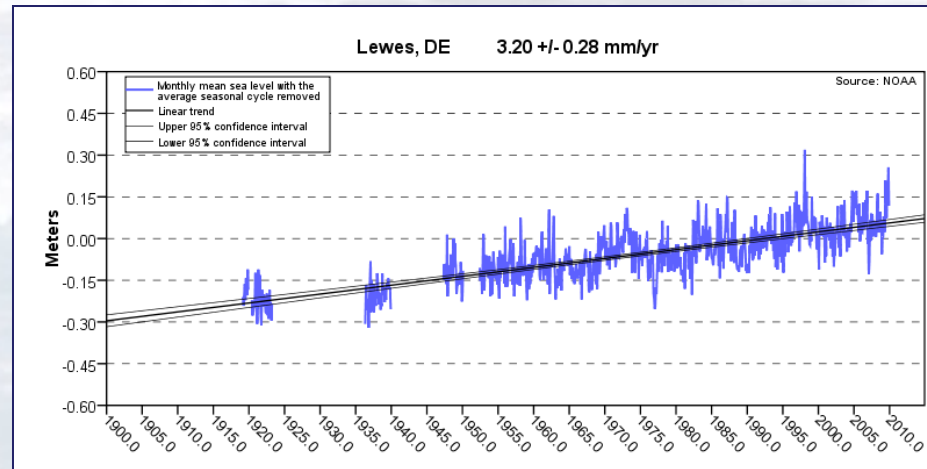
# Delaware Sea Level Trends



**Global SLR 1.7 mm/yr**

**DE-SLR 3.4 mm/yr**

Source: NOAA





# It's Not Just Sea Level Rise

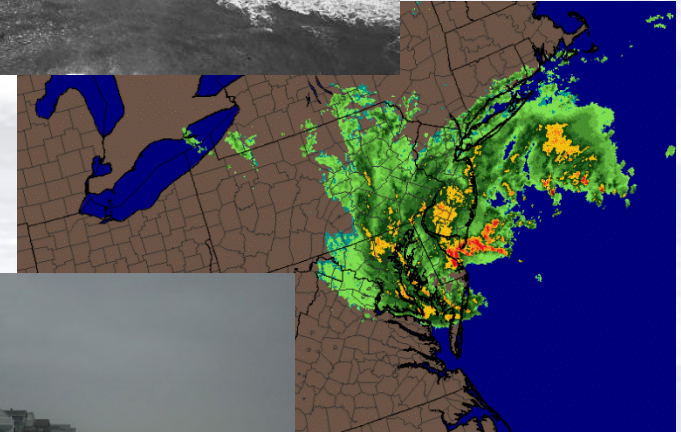
- If we plan for Sea Level Rise we will inherently increase protection from Coastal Storms
  - ✓ Coastal Storms have occurred and will continue to occur





# Delaware Coastal Storms

- '62 Storm
  - Lewes
    - ✓ 4.5 ft above MHHW
- Mothers Day Storm 2008 – Bowers Beach
  - ✓ 4 ft above MHHW
- Veterans Day Storm 2009 – Lewes
  - ✓ 3 ft above MHHW



# Summary

- Climate Change/Sea Level Change is an ongoing process
- The Earth's Climate is a delicate balance
- There are many variables involved in predicting climate change
- We must plan for increased sea level rise using the best available knowledge



# Questions

